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COLLEGE. E. L. MARK, DIRECTOR.

No. 140.

ON THE NEGATIVE AND POSITIVE PHOTOTROPISM OF THE EARTHWORM ALLOLOBOPHORA FŒTIDA (SAV.) AS DETERMINED BY LIGHT OF DIFFERENT INTENSITIES.

BY GEORGE P. ADAMS.

WITH TWO FIGURES.

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CAMBRIDGE, MASS., U.S.A.
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CONTRIBUTIONS FROM THE ZOÖLOGICAL LABORATORY OF THE MUSEUM OF COMPARATIVE ZOÖLOGY AT HARVARD COLLEGE. E. L. MARK, DIRECTOR. No. 140.

ON THE NEGATIVE AND POSITIVE PHOTOTROPISM OF THE EARTHWORM ALLOLOBOPHORA FŒTIDA (SAV.) AS DETERMINED BY LIGHT OF DIFFERENT INTENSITIES.

BY GEORGE P. ADAMS.

THAT earthworms are negatively phototropic, that is, creep away from a source of light, has been frequently demonstrated, and the extent to which this is true has already been roughly estimated for Allolobophora fœtida. Parker and Arkin (:01, p. 154) found that when this worm was illuminated on the whole of one side by a light of 3.3 to 4.0 candle-metres intensity, 30.2 per cent of the head movements were away from the light. Of these, however, 4.2 per cent were due to other deflecting causes than light, and hence 26 per cent may be taken as a measure of the deflecting effect of the light. Miss Smith (:02, p. 469) carried out similar experiments, but by slightly different methods, and found that 61 per cent of the reactions were in a generally negative direction. If Miss Smith's results are interpreted in the way in which Parker and Arkin's were, it would appear that 61 per cent less 22 per cent, or 39 per cent, is the proportion of reactions to be attributed to the deflecting effect of the light. Thus, there is a disagreement in the two sets of records amounting to the difference between 39 per cent and 26 per cent. This disagreement may be due to differences in the intensities of the light used in the two sets of experiments. Miss Smith carried on her experiments in diffuse daylight, but as she gives no data from which the intensity can be calculated, this assumption may or may not be correct.

The present investigation was made under the direction of Dr. G. H. Parker, to ascertain the relation between the intensity of the light to which the earthworm Allolobophora fœtida (Sav.) was exposed, and its negative phototropic reactions; and to find out under what conditions, if any, the reactions would become positive. Inversions in the sense of the phototropism have already been recorded for a number of animals. Thus, Wilson ('91, p. 414) has shown that Hydra is negative to bright light, and positive to dim light; and the same has been demonstrated for Polygordius larvæ by Loeb ('93, p. 89), for Limax by Frandsen (:01, p. 206), and for the females of the Copepod Labidocera æstiva by Parker (:02, p. 114). In these instances negative phototropism is associated with an increased intensity of light, and this seems to be a general rule, though there is at least one exception to it, namely, in Orchestia agilis. This crustacean, as reported by Holmes (:01, p. 216), becomes positive in bright light, but is subsequently negative when transferred to diffuse daylight.

In testing Allolobophora fœtida, twelve different intensities of light were used, ranging from 192 candle-metres to 0.001 candle-metre. The first set of experiments was made with one piece of apparatus, using eleven different intensities. The second set was carried on with another apparatus, using the lowest intensity of light, 0.001 candle-metre. A third set of experiments, devised to check any disagreement between the results of the other two sets, due to a difference in the apparatus, was carried on with both pieces of apparatus, using the same light intensity for each.

The first apparatus (Fig. 1), which may be called the high-intensity apparatus, was essentially the same as that used by Parker and Arkin (:01, pp. 151–152). It consisted of a dark chamber (*C*) illuminated only through a horizontal oblong opening by a distant incandescent electric lamp (*B*). A glass jar (*A*), with parallel sides 6.25 cm. apart, and containing water, was placed immediately in front of the lamp to cut off heat. Within the dark chamber, directly in the path of the beam of light coming through the oblong opening, was a glass plate (*G*), suspended so that it was horizontal and could be easily rotated about its vertical axis. The glass was covered with wet filter paper, which was frequently changed. The light intensity is given for each experiment in candle-metres, and is the intensity of the beam of light at the centre of the plate. In all cases, the candle-power of the incandescent lamp was determined by a Lummer-Brodhun photometer.

In the first set of experiments, for each of the eleven light intensities, twenty fresh worms were used. Each worm was headed across the filter paper on the glass plate in a direction at right angles to the rays of light. As the worm crept, the plate was rotated, so that the axis of the worm was kept constantly at right angles to the direction of the light. Ten readings were taken on each worm; five with the light falling on the worm's right side, and five with the light on the left side. Thus, for each intensity, there were two hundred readings. As is well known, the worm creeps by projecting the head forward, and then drawing the body toward the head. When the worm projected the head in a line with the axis of the posterior part of the body, the reaction was called indifferent (0); when the head was moved to one side, if it was toward the light, the reaction was called positive (+); if away from the light, negative (–). For each of the eleven intensities, there was a total excess of negative over positive reactions. By subtracting the positive from the negative reactions, the number of negative reactions due to the directive influence of the light was obtained; for, since the positive reactions are not caused by the light, but by other influences, such as irregularities of the surface over which the worm is creeping, etc., it is clear that an equal number of the negative reactions are likely to be caused by these other influences, and it is, therefore, necessary to subtract the number of these from the total number of negative reactions, to get the real number of such reactions due to light only.

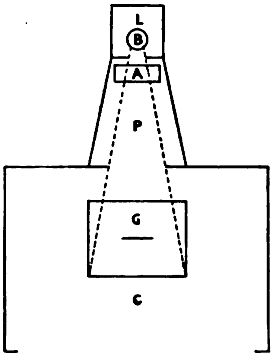

FIGURE 1. — Ground plan of high-intensity apparatus. *A*, glass vessel containing water to intercept heat rays; *B*, incandescent electric lamp; *C*, dark-chamber; *G*, glass plate covered with wet filter paper upon which the worms were made to creep; *L*, lantern; *P*, light-proof passage used by Parker and Arkin, but omitted in these experiments because the apparatus was set up in a dark-room with blackened wall.

Table I gives the result of the first set of experiments. The light intensities in candle-metres are given in the first column on the left. In the next two groups of columns are given, for the right and left sides respectively, the number of times the worm moved indifferently (0), negatively (–), and positively (+), and the excess of negative over positive reactions. In the third group, the total reactions of the worm for both sides are given.

From an inspection of the third group of the table, it appears that the maximum number of reactions to be attributed to the directive influence of the light is found, not in the most intense light, but in the third intensity used, 48 candle-metres. From this intensity there is a rather constant decrease in the amount of this excess, corresponding with a decrease of light intensity. The lowest intensity used with this apparatus, 0.012 candle-metre, shows an excess of only 6 negative reactions out of a total of 200. There is also a less regular increase in the number of positive reactions, as the light becomes less intense.

TABLE I.

REACTION OF ALLOLOBOPHORA TO LIGHT OF DIFFERENT INTENSITIES.

Light intensity in candle-metres.	Reactions with light on right side of worm.				Reactions with light on left side of worm.				Total reactions of worm.			
	0	—	+	Excess of — over +.	0	—	+	Excess of — over +.	0	—	+	Excess of — over +.
192	30	58	12	46	35	51	14	37	65	109	26	83
90	42	53	5	48	51	42	7	35	93	95	12	83
48	36	62	2	60	34	62	4	58	70	124	6	118
31	47	46	7	39	39	56	5	51	86	102	12	90
12	43	53	4	49	46	48	6	42	89	101	10	91
5	52	43	5	38	47	46	7	39	99	89	12	77
1	62	30	8	22	53	37	10	27	115	67	18	49
0.128	44	36	20	16	50	31	19	12	94	67	39	28
0.050	40	35	25	10	32	41	27	14	72	76	52	24
0.020	40	32	28	4	44	31	25	6	84	63	53	10
0.012	49	26	25	1	51	27	22	5	100	53	47	6

The record for negative light reactions (26 per cent) for the single intensity of about 3.6 candle-metres obtained by Parker and Arkin finds an appropriate place in this table, in that, falling between 5 candle-metres and 1 candle-metre, its negative light reaction (26 per cent) also falls between those of 5 (38.5 per cent) and of 1 (24.5 per cent), though the position is not one that yields smooth results. The fact that the number of negative light reactions varies with the intensity makes it highly probable that the difference between the records of Parker and Arkin, and those of Smith, are to be explained as due to difference of intensity. Judged from the series exhibited in Table I, the intensity of light used by Smith was not far from 5 candle-metres, a condition easily obtainable from diffuse daylight.

The decrease in the excess of negative over positive reactions corresponding with a decrease of light intensities suggested that if the light were still further decreased, the negative light reactions might entirely disappear, or even be replaced by positive ones. To test this, the first piece of apparatus could not be used, because at intensities of light lower than 0.01 candle-metre it was found impossible to follow with the eye the movements of the worm. To obviate this difficulty, the second piece of apparatus was devised. This apparatus (Fig. 2), which may be called the low-intensity apparatus, consisted of two dark chambers in contact with each other, shown in plan in the figure. In the first chamber (*A*), a vertical white screen (*CD*) was placed in a diagonal position, so that it reflected light from an electric incandescent lamp (*E*) through a small aperture (*F*) between the two chambers. This reflected light entered the second chamber (*B*), and there passed over a horizontal glass plate (*G*). It was found that when the relations of the light, screen, and plate were such as are given in the diagram, with an incandescent lamp of 8.25 candle-power, and a circular aperture of 1 mm. diameter, an illumination of 0.0011 candle-metre was obtained at the centre of the plate. Wet filter paper was used on the plate, and two thick, narrow strips of glass (*HH*), like those employed by Smith (:02), were placed on the filter paper in parallel positions, with only enough space between them to allow the worm to creep. This narrow path between the two strips was in a direction at right angles to the central rays of light which came through the aperture. After starting the worm in this path, the chambers were closed so as to exclude all outside light. Time enough was given to allow the worm to creep into the field beyond the two strips of glass; chamber *B* was then opened, and the position of the worm noted. If the worm was headed toward the light, it was called a positive reaction; if away from the light, a negative one; and if the worm had moved without changing its original direction, an indifferent one.

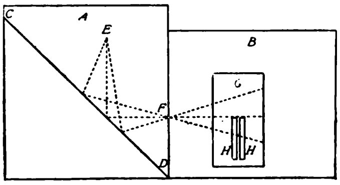

FIGURE 2.

Twenty fresh worms were used as before, and for each worm two sets of readings were made. In one set, the worm was illuminated by the beam of light of 0.0011 candle-metre intensity; in the other set, the aperture was closed, that is, the worm was in total darkness.

TABLE II.

REACTIONS OF ALLOLOBOPHORA TO LIGHT OF 0.0011 CANDLE-METRE, AND IN DARKNESS.

Number of worm.	0.0011 candle-metre.				Darkness.			
	0	+	−	Excess of + over −.	0	+	−	Excess of + or of −.
1	0	7	3	4	1	2	7	5−
2	0	8	2	6	0	5	5	0
3	0	6	4	2	0	6	4	2+
4	0	6	4	2	0	7	3	4+
5	0	6	4	2	0	7	3	4+
6	0	5	5	0	0	5	5	0
7	0	7	3	4	2	5	3	2+
8	0	5	5	0	1	5	4	1+
9	1	5	4	1	0	4	6	2−
10	0	8	2	6	0	4	6	2−
11	0	8	2	6	0	6	4	2+
12	0	6	4	2	0	7	3	4+
13	0	8	2	6	1	4	5	1−
14	0	8	2	6	0	4	6	2−
15	0	6	4	2	1	5	4	1+
16	1	8	1	7	0	6	4	2+
17	0	8	2	6	1	4	5	1−
18	0	7	3	4	0	3	7	4−
19	0	9	1	8	0	6	4	2+
20	1	7	2	5	0	5	5	0
Totals	3	138	59	79+	7	100	93	7+

In each set, ten readings were made on each worm, five with the worm's right side toward the aperture, which in one set was open and in the other closed, and five with the left side toward the aperture.

Table II gives the reactions of the twenty worms. The readings of the right and left sides of the worm have been combined. In the first column on the left is given the number of the worm. In the left-hand group of columns are given the reactions of the worm in light of 0.0011 candle-metre; and in the right-hand group are given the reactions in darkness. At the bottom, the total reactions for the twenty worms are recorded (see Table II, page 31).

It appears, first, that there is a great reduction in the number of indifferent movements over the number obtained with the first piece of apparatus. This is explained by the fact that in the second apparatus the slightest deviation of the worm from the indifferent path, which was marked by a pencil line on the filter paper, could be observed; and thus many reactions which would have been recorded as indifferent in the first apparatus were here shown to be either positive or negative. Of the reactions of the worms in total darkness, in all 200, 7 were indifferent, 100 were toward the aperture (which was now closed), and 93 were away from it. The 200 reactions of the same worms in light of 0.0011 candle-metre at the plate, were as follows: 3 were indifferent, 138 were toward the light, and 59 were away from the light, there being an excess of 79 positive reactions. Moreover, there was never found an excess of negative over positive movements in the case of any worm. This clearly points to the conclusion that light of low intensity induces positive phototropic reactions.

To ascertain whether the results obtained by the high-intensity and by the low-intensity apparatus were fairly comparable, a third set of experiments was tried, in which worms were tested at the same light intensity (1 candle-metre) in both pieces of apparatus. Twenty fresh worms were used, each one first in one apparatus, and then in the other. In each apparatus, ten readings were made, five with the light on the right side, and five with it on the left side of the worm.

Table III shows the result of this set of experiments. The figures given are the totals for the twenty worms, right and left sides combined (see Table III, page 33).

A much larger number of indifferent movements were obtained on the high-intensity apparatus, but the total excess of negative over positive movements is so nearly alike for each (25 per cent and 29 per cent), that one may assume that the records of the two sets of experiments are fairly comparable, and therefore, from the observations recorded in Tables I and II, draw the conclusion that Allolobophora fœtida is negative to light intensities between 192 and 0.012 candle-metres, and positive at 0.0011 candle-metre.

The results of these experiments are in harmony with certain daily habits of earthworms. During the daytime, while the light is of relatively high intensity, these animals retreat into their burrows because of negative phototropism. At night-time, however, they emerge from their burrows, not because of the absence of light, but by reason of their positive phototropism to light of low intensity, for even in the darkest night there is faint light.

TABLE III.

Direction of reactions.	0	−	+	Excess of − over +.
High-intensity apparatus . .	96	77	27	50
Low-intensity apparatus . .	4	127	69	58

CONCLUSIONS.

1. Allolobophora fœtida is *negatively* phototropic toward the light from electric incandescent lamps varying in intensity from 192 candle-metres to 0.012 candle-metre; the percentage of negative head-movements referable to lights of different intensities are as follows: 41.5 per cent (192 cm.), 41.5 per cent (90 cm.), 59 per cent (48 cm.), 45 per cent (31 cm.), 45.5 per cent (12 cm.), 38.5 per cent (5 cm.), 24.5 per cent (1 cm.), 14 per cent (0.128 cm.), 12 per cent (0.050 cm.), 5 per cent (0.020 cm.), and 3 per cent (0.012 cm.).

2. A. fœtida is *positively* phototropic toward an electric incandescent lamp of 0.0011 candle-metre intensity.

3. Earthworms retreat into their burrows during daytime because of their negative phototropism. They emerge at night not so much because of darkness as because of their positive phototropism for faint light.

BIBLIOGRAPHY.

FRANDSEN, P.

:01. Studies on the reaction of Limax maximus to directive stimuli. Proceedings of the American Academy of Arts and Sciences, xxxvii, pp. 185–227.

HOLMES, S. J.

:01. Phototaxis in the Amphipods. American journal of physiology, v, pp. 211-234.

LOEB, J.

'93. Ueber künstliche Umwandlung positiv heliotropischer Thiere in negativ heliotropische und umgekehrt. Archiv für die gesammte Physiologie, liv, pp. 81-107.

PARKER, G. H.

:02. The reactions of Copepods to various stimuli, and the bearing of this on daily depth migrations. Bulletin United States Fish Commission for 1901, pp. 103-123.

PARKER, G. H., and ARKIN, L.

:01. The directive influence of light on the earthworm Allolobophora fœtida (Sav.). American journal of physiology, iv, pp. 151-157.

SMITH, AMELIA C.

:02. The influence of temperature, odors, light, and contact on the movements of the earthworm. American journal of physiology, vi, pp. 459-486.

WILSON, E. B.

'91. The heliotropism of Hydra. American naturalist, xxv, pp. 413-433.

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E. L. Mark, *Director*.

⁂ Abbreviations used:—

B. M. C. Z. . . . . for Bull. Mus. Comp. Zoöl.
P. A. A. . . . . for Proceed. Amer. Acad. Arts and Sci.
P. B. S. N. H. . . . . for Proceed. Bost. Soc. Nat. Hist.

1. Barnes, W. — On the Development of the Posterior Fissure of the Spinal Cord, and the Reduction of the Central Canal, in the Pig. P. A. A. **19**: 97–110. 3 pls. 1884.
2. Tuttle, A. H. — The Relation of the External Meatus, Tympanum, and Eustachian Tube to the First Visceral Cleft. P. A. A. **19**: 111–132. 2 pls. 1884.
3. Ayers, H. — On the Development of Oecanthus niveus and its Parasite, Teleas. Mem. Bost. Soc. Nat. Hist. **3**: 225–281. 8 pls. Jan., 1884.
4. Whitman, C. O. — The External Morphology of the Leech. P. A. A. **20**: 76–87. 1 pl. Sept., 1884.
5. Patten, W. — The Development of Phryganids, with a Preliminary Note on the Development of Blatta Germanica. Quart. Journ. Micr. Sci. **24**: 549–602. 3 pls. 1884.
6. Reighard, J. — On the Anatomy and Histology of Aulophorus vagus. P. A. A. **20**: 88–106. 3 pls. Oct., 1884.
7. Faxon, W. — Descriptions of New Species of Cambarus; to which is added a Synonymical List of the Known Species of Cambarus and Astacus. P. A. A. **20**: 107–158. Dec., 1884.
8. Locy, W. — Observations on the Development of Agelena naevia. B. M. C. Z. **12**: 63–103. 12 pls. Jan., 1886.
9. Fewkes, J. W. — Report on the Medusae collected by the U. S. Fish Commission Steamer Albatross in the Region of the Gulf Stream in 1883-'84. Ann. Rep. Comnr. Fish and Fisheries for 1884, 927–980, 10 pls., 1886.
10. Ayers, H. — On the Carapax and Sternum of Decapod Crustacea. Bull. Essex Inst. **17**: 49–59. 2 pls. 1886.
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19. Davenport, C. B. — Cristatella: The Origin and Development of the Individual in the Colony. B. M. C. Z. **20**: 101–151. 11 pls. Nov., 1890.
20. Parker, G. H. — The Eyes in Blind Crayfishes. B. M. C. Z. **20**: 153–162. 1 pl. Nov., 1890.

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24. **Woodworth, W. M.** — Contributions to the Morphology of the Turbellaria. — I. On the Structure of Phagocata gracilis, Leidy. B. M. C. Z. **21**: 1–44. 4 pls. Apr., 1891.

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✓ 28. **Davenport, C. B.** — Observations on Budding in Paludicella and some other Bryozoa. B. M. C. Z. **22**: 1–114. 12 pls. Dec., 1891.

D 10[illegible]7
D 24

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✓ 33. **Davenport, C. B.** — On Urnatella gracilis. B. M. C. Z. **24**: 1–44. 6 pls. Jan., 1893.

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34. **Davenport, C. B.** — Note on the Carotids and the Ductus Botalli of the Alligator. B. M. C. Z. **24**: 45–50. 1 pl. Jan., 1893.

✓ 35. **Ritter, W. E.** — On the Eyes, the Integumentary Sense Papillae, and the Integument of the San Diego Blind Fish (Typhlogobius californiensis, Steindachner). B. M. C. Z. **24**: 51–102. 4 pls. Apr., 1893.

D 1339
R61

36. **Nickerson, W. S.** — The Development of the Scales in Lepidosteus. B. M. C. Z. **24**: 115–140. 4 pls. Jul., 1893.

✓ 37. **Davenport, C. B.** — Studies in Morphogenesis. — I. On the Development of the Cerata in Æolis. B. M. C. Z. **24**: 141–148. 2 pls. Jul., 1893.

D 1499
D24

38. **Woodworth, W. McM.** — A Method of Orienting small Objects for the Microtome. B. M. C. Z. **25**: 45–47. Dec., 1893.

39. **Kofoid, C. A.** — On some Laws of Cleavage in Limax. P. A. A. **29**: 180–203. 2 pls. 1894.

40. **Davenport, C. B.** — Studies, etc. — II. Regeneration in Obelia and its Bearing on Differentiation in the Germ-Plasma. Anat. Anz. **9**: 283–294. 6 figs. Feb. 15, 1894.

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45. **Miller, Gerrit S., Jr.** — On the Introitus Vaginæ of certain Muridæ. P. B. S. N. H. **26**: 459–468. 1 pl. Feb., 1895.

✓ 46. **Davenport, C. B., and Castle, W. E.** — Studies, etc. — III. On the Acclimatization of Organisms to High Temperatures. Arch. f. Entwickelungsmechanik **2**: 227–249. Jul. 23, 1895.

47. **Wilcox, E. V.** — Spermatogenesis of Caloptenus femur-rubrum and Cicada tibicen. B. M. C. Z. **27**: 1–32. 5 pls. May, 1895.

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✓ 50. **Davenport, C. B.** — Studies, etc. — IV. A preliminary Catalogue of the Processes concerned in Ontogeny. B. M. C. Z. **27**: 171–199. 31 figs. in text. Nov., 1895.

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✓ 54. **Parker, G. H., and Floyd, R.** — Formaldehyde, Formaline, Formol, and Formalose. Anat. Anz. **11**: 567, 568. Feb. 14, 1896.

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63. **Woodworth, W. McM.** — Preliminary Report on Collections of Turbellaria from Lake St. Clair and Charlevoix, Michigan. Bull. Michigan Fish Commission, No. **6**: 94, 95. 1896.

64. **Goto, S.** — Preliminary Notes on the Embryology of the Starfish (Asterias pallida). P. A. A. **31**: 333–335. Jul., 1896.

65. **Woodworth, W. McM.** — Report on the Turbellaria collected by the Michigan State Fish Commission during the Summers of 1893 and 1894. B. M. C. Z. **29**: 237–244. 1 pl. Jun., 1896.

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73. **Davenport, C. B., and Bullard, C.** — Studies, etc. — VI. A Contribution to the Quantitative Study of Correlated Variation and the Comparative Variability of the Sexes. P. A. A. **32**: 87–97. Dec., 1896.

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